INELASTIC BEHAVIOR AND NUMERICAL ANYLISIS IN TWIN-ROLL CASTING PROCESS OF AZ31 ALLOY

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1. Introduction

Twin-roll casting process is a rapid solidification process combining with hot rolling. In the process molten metal was solidified starting at the point of first metal-roll contact and ending before the kissing point. This near-net-shape process can directly produce thin strips in one step. It has more advantages due to its higher productivity, low cost and energy saving. Therefore more and more researchers have concentrated their studies on the processes [1]..

In twin roll casting process rolling action play an important role and the liquid metal will be squeezed out from the mush zone, which is very different from the conventional continuous casting process. In this work, we focuses the research work on the constitutive equation, stresses and deformation study, other aspects will be simplified. A 2D FEM model was employed and use sequential coupled analysis method to simulate the thermal mechanical behavior during twin-roll casting process of Mg alloy AZ31. Here, the Anand's model, a temperature and rate dependent model for high temperature deformation, was employed to calculate the thermal mechanical stress in the casting process. Based on the stresses analysis and experimental tests, it reveals that separating force should be strictly controlled in the twin roll casting process in order to avoid cracks caused by thermal and deformation stresses.

2. Inelastic constitute equation

In twin-roll thin strip casting process, stresses primarily arise due to high thermal gradient and rolling deformation. The total strain rate can be decomposed as:

$$\dot{\varepsilon}_{ij} = \dot{\varepsilon}_{ij}^{e} + \dot{\varepsilon}_{ij}^{p} + \dot{\varepsilon}_{ij}^{Th} \tag{1}$$

where $\dot{\varepsilon}_{ij}^{e}, \dot{\varepsilon}_{ij}^{p}, \dot{\varepsilon}_{ij}^{Th}$ were elastic, plastic and thermal strain rate, respectively. Elastic strain rate, thermal strain rate are given by:

$$\dot{\sigma}_{ij} = E_{ijkl}(T)\dot{\varepsilon}_{kl}^{e} \tag{2}$$

$$\dot{\varepsilon}_{ij}^{Th} = \alpha \Delta \dot{T} \delta_{ij} \tag{3}$$

where $E_{ijkl}(T)$ is the temperature dependent elastic modulus. And $\Delta\dot{T}$ is the change rate of current temperature and the reference temperature at the point, α is thermal coefficient of expansion. The plastic strain rate $\dot{\varepsilon}_{ij}^{p}$ is described by Anand model, which is a temperature and rate dependent model for high temperature large deformation process. A set of internal type constitutive equations for large elastic-viscoplastic deformation at high temperature was proposed by Anand and Brown [2]. The specific functional form for the flow equation:

$$\dot{\bar{\varepsilon}}^{p} = A \exp\left(-\frac{Q}{R\theta}\right)\left[\sinh\left(\xi \frac{\tilde{\sigma}}{s}\right)\right]^{1/m} \tag{4}$$

and the specific functional form of evolution equation for the internal variable s

$$\dot{s} = \left\{ h_0 \left| \left(1-\frac{s}{s^*}\right) \right|^a sign\left(1-\frac{s}{s^*}\right) \right\} \dot{\varepsilon}^p ; \qquad a > 1 \tag{5}$$

$$s^* = \tilde{s}\left[\frac{\dot{\varepsilon}^p}{A}\exp\left(\frac{Q}{RT}\right)\right]^n \tag{6}$$

where h_0 is the hardening constant, A is the strain rate sensitivity of hardening, s* is the saturation value of s, $\tilde{s}$ is a coefficient, and n is the strain rate sensitivity for the saturation value of deformation resistance, respectively. The nine parameters of Anand constitutive model A, Q, ξ, m, h_0, $\tilde{s}$, n, a and s_0 (the initial value of s) can be obtained from curve-fitting of compression tests, by which large strain and fully developed plastic flow can be achieved due to the absence of necking. Isothermal constant true strain rate tests of AZ31 with different strain rates and temperatures were carried out, the true strain versus stress curves were shown in Fig. 1.The parameters of Anand model regressed from comparison tests are A: 3.5x107s^{-1}, Q: 160kJ/mol, ξ: 8.5, m: 0.28, h_0: 3.038x109Pa, n: 0.018, a: 1.07, s_0: 3.5x10^7Pa, $\tilde{s}$: 5x107Pa. Fig.3. show the prediction and experimental strain vs. stress curves.

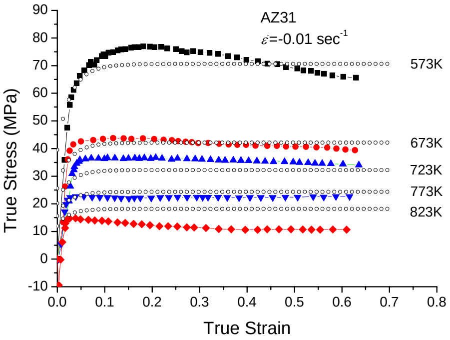

Fig. 1. Prediction and experimental compression true strain vs. stress curves at different temperatures

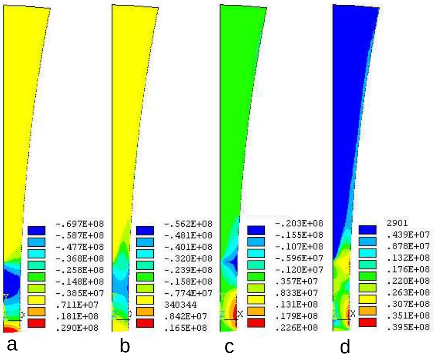

Fig. 2. Contours of σ_x (a), σ_y (b), σ_{xy} (c) and von Mises stress (d)

3 Thermal Stresses

In this study, the simulation model was employed to calculate stresses. The thermal flow result of temperature field was imposed as body load and the reference temperature was set as the average temperature of strip surface. The strip surface set as free surface because solidifying shrinkage.To simulate rolling action in twin-roll casting process, displacement load along roller tangent direction was imposed. The results of stresses and deformations were shown in Fig. 2. The stress status of strip surface along casting direction was tensile stress; this is one of main reasons causing strip crack defects.

4. Conclusion

The deformation of twin-roll casting process is non-uniformed because of high temperature gradient.; the backward squeeze zone and the exit zone are the two dangerous regions for cracks.Rolling actions is much dangerous than thermal stress. Control the solidification end near the kissing point can decrease rolling deformation and decrease the crack tendency.

References

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